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Gas Sensors for Health Monitoring and Diagnostics

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Technology description

The Need

Exhaled human breath is a combination of hundreds of gases including inorganic molecules such as NO, NH3 or CO, and volatile organic molecules such as acetone, ethane, and isoprene. Some of these gases are produced by the body as the result of physiological processes. Known as 'biomarkers' these gases may be indicative of metabolic health or the presence of a disease within the individual. Abnormal concentrations of these biomarkers in exhaled breath may accordingly aid in the detection and diagnoses of such infirmities, as well as afford opportunities to study an individual's biophysical and physiological reaction to various stimuli. Few human breath tests exist to-date to measure such biomarkers.

The tools currently the biomarker detection are too expensive (e.g. Sievers NO; GC-MS systems) and cumbersome (e.g. aerocrine Vero). Current breath analyzing devices are large, costly, and mostly dependent on prohibitively large sample volumes. Others require the patient to consume chemical receptors prior to testing. These drawbacks prohibit breath analysis technologies from being the easy, quick and non-invasive diagnostic tool that they could be. A need exists for economical gas sensors that can detect these sufficiently gas markers in order for breath analyzers to make diagnostic advancements.

Prof. Gouma's portfolio offers technologies for portable, handheld single exhale breathalyzers for signaling metabolites involving selective sensors which are able to monitor the concentration of a single gas in a complex mixture, and in the case of certain diseases which lack a single specific biomarker the sensors or sensor array may be able to discriminate multiple disease markers from a single sample.

The Technology

Dr. Pelagia-Iren "Perena" Gouma and her research group have developed a range of low-cost gas sensors capable of measuring various biomarkers in exhaled breath. The semiconducting metal oxide (SMO) gas sensors rely on the polymorphic characteristics of metal oxides to be gas-selective, improving on previous SMO sensor technology which had trouble targeting a specific gas. The sensors can selectively measure, among other molecules: acetone, ammonia, isoprene, and nitric oxide. These gases are known to be breath markers of unique physiological origin and possibly indicative of disease.

The sensors developed by Dr. Gouma have also been integrated into hand-held breath analyzing devices which demonstrate their efficacy as diagnostic tools.

The researchers led by Dr. Gouma have also developed ferroelectric and mixed oxide sensor technology which uses a similar crystallochemical approach to selectively monitor different gases based on the crystalline structure and temperature of the oxide elements.

Nitric Oxide Sensors (Patented)

Dr. Gouma's original research resulted in the development of a variety of metal oxide resistive gas sensors based largely on the various crystalline phases of tungsten trioxide and molybdenum oxide. The sensors include a thin film of metal oxide and exhibit a highly selective change in resistance in the presence of a selected gas.

The metal oxide sensor based on γ-phase $W0_3$ uses chemo-resistive technology which can detect NO concentrations of a few parts-per-million with a high sensitivity and specificity. The sensor has been shown to successful detect sufficient levels of NO in exhaled breath for diagnostic purposes. The NO sensor may be used alone or in combination with other sensors in an array for the measurement and diagnosis of various health conditions such as asthma, lung disease, and hypoxia-related infirmities.

Isoprene Sensors (Patent Pending)

Further developing SMO sensor technology, Dr. Gouma has invented a new metal oxide sensor using hexagonal-phase tungsten trioxide (h-WO_3) that when kept stable is highly selective for isoprene. The sensor has been integrated into a handheld single-sensor device for breath analysis to demonstrate the ability of Dr. Gouma and her team to both stabilize theh-WO_3 in an efficient manner and to selectively sense for isoprene at thresholds high enough for the sensor to be possible the first isoprene-selective chemical sensor capable of being include in a portable device.

Unusual levels of isoprene in exhaled breath may indicate a sleeping disorders or high-altitude diseases and symptoms such as block-out from hypoglycemic shock. An isoprene sensor can also be paired with a NO sensor for active monitoring of pilots and hypoxia-related conditions.

Ammonia Sensors (Patented)

Using alpha-phase molybdenum trioxide (α-MoO_3) the team has also created a chemo-selective ammonia gas sensor. Ammonia is an important biomarker that previously has been difficult to measure in trace concentrations economically. The sensor developed by Dr. Gouma can selectively measure ammonia in parts-per-billion concentrations in exhaled breath, resulting in an inexpensive and rapid-result chemoreceptive sensor for single or multi-sensor use.

Detection of abnormal concentrations of ammonia can be indicative of uremia, kidney failure, and hemodialysis endpoint.

Acetone (Patented)

In addition to chemoresistive sensors, Dr. Gouma and her team have developed a ferroelectric poling sensor capable of selectively measuring acetone. Using epsilon-phase tungsten trioxide (ε-WO_3) prepared by flame spray pyrolysis the sensor is capable of measuring concentrations below 1 ppm, which is sufficient for monitoring diabetes in a non-invasive manner. Acetone monitoring is in fact more sensitive than blood glucose levels for the monitoring of diabetes. Acetone monitoring may also be useful in diet control situations as an indicator of metabolic rate.

Multi-Sensor Arrays (Patented)
Not only has Dr. Gouma and her team developed discrete sensors capable of measuring a range of analytes, they have also recognized the potential for multi-sensor arrays to monitor and measure multiple gases in a single stream as a diagnostic tool.
For example, the team has developed a novel three-sensor array system to detect flu infection. The sensor array responds to a single exhaled breath and analyzes it with respect to concentrations of nitric oxide, isoprene and ammonia. The low cost, portability, and quick response time may allow for earlier identification of infected patients, which would cut down on dramatically on treatment costs.

Application area

Monitoring asthma
Monitoring diabetes control with more accuracy then typical blood glucose testing
Non-invasive monitoring of blood cholesterol
Diagnosing lung disease, sleep disorders, hypoxia-related conditions, and influenza
Near-continuous monitoring of metabolic activity
Non-invasive medical diagnostic tool

Advantages

Inexpensive
Highly selective
Rapid
Portable

Institution

The Ohio State University

Inventors

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